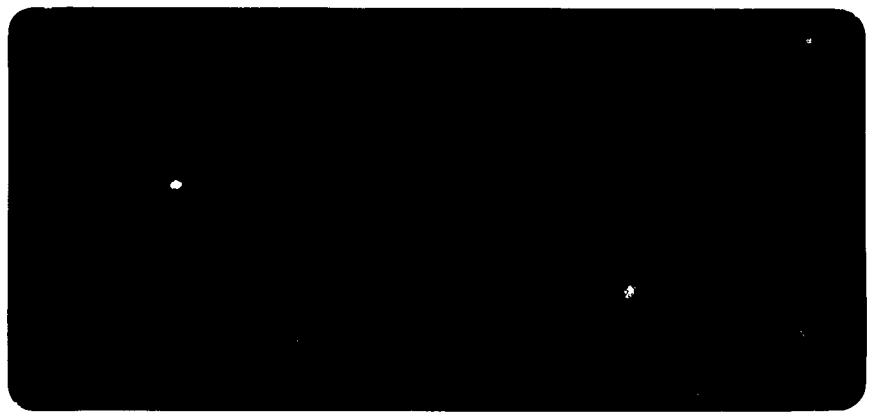

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SECOND SEMI-ANNUAL REPORT - PHASE II

ABSTRACTS OF MATERIAL EVALUATION PROGRAMS CONDUCTED AT CHANCE VOUGHT CORPORATION

Contract AF 33(616)-7986
Task No. 73812

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 Since this is a progress report, the information herein is tentative and subject to changes, corrections, and modifications.

ABSTRACT

This is the second semi-annual report in a program designed to collect and disseminate abstracts on material evaluation programs being conducted at Chance Vought Corporation during the current reporting period. The material contained in this report consists of abstracts of test programs conducted on aluminum, columbium, magnesium, nickel base alloys, plastics, and zirconia.

CONTENTS

BIAXIAL FATIGUE TESTS OF BARE 7075-T6 ALUMINUM

Purpose

The purpose of these tests was to evaluate a specimen configuration for use under low-cycle biaxial fatigue loading conditions under both one to one and two to one loading ratios.

Test Specimen

The basic specimen which was selected for use in this investigation was a symmetrical cross with a diamond shaped depression in the test section.

Test Procedure

The specimen was mounted in a floating jig which eliminates load eccentricities. Strain gages were mounted in appropriate locations in the machined depression to monitor the principal strains during initial loading of the specimen, and periodically during the cycling in order to maintain the desired load levels.

Conclusions

Initial observations indicated that grip-end failures might be expected due to the high load levels being used during these tests. These observations were verified when early specimens failed in this area. After the loading grip problem was overcome, three specimens were cycled under one to one loading at R = 0.10. All specimens were unnotched. All specimens failed due to fatigue in the area of the one to one stress condition.

The first specimens tested under two to one loading failed in the reduced section, close to, but not in the exact area of two to one stresses. A second depression was then machined into the reduced section to peak the stresses. This was effective in producing satisfactory fatigue failures in the desired area.

These tests indicate that satisfactory biaxial fatigue tests may be conducted on flat specimens machined from sheet material without resorting to the use of simulated pressure vessels or similar test articles.

A proposal for low cycle biaxial fatigue testing with this specimen has been submitted to ASD and is currently being evaluated.

DIFFUSION COATING PROCESS FOR COLUMBIUM BASE ALLOYS
Contract AF33(616)-7896

Introduction

Although a number of coatings for refractory metals have been developed using the pack cementation process, they have usually been realized through "trial and error" techniques without a thorough investigation of the many variables. No completely satisfactory coating specifically for columbium and its alloys has been reported in the literature.

This program is an integrated sequence of study, development and testing initiated to accomplish the optimization of the best available coating system and its required processing technologies for the oxidation protection of columbium alloys. As a result of this work, coatings for columbium sheet alloys will be optimized with respect to reliability and reproducibility.

Phase I of the program includes a study of the available data and review of process and material variables with respect to their effect on the coating integrity. The end use application has been given consideration in the design of test methods and requirements for maximum temperature. The analysis of available data has been focused on structure designed for severe service to 2600°F.

Phase II of the program is an investigation of process variables which will involve a series of tests using the most promising coating systems based on results of the first phase. A single alloy, Cb-1 Zr, will be used to establish the precise effect each variable has upon coating integrity. Selected tests will be conducted to establish the significant variables with respect to optimizing the coating systems.

Phase III of the program is divided into three parts as follows: (1) determination of process reliability and reproducibility using information and data from Phase II, (2) selection of techniques for coating complex multi-component assemblies, and (3) delivery of coated test specimens and test assembly to ASD.

Procedures

The following Phase I tests are covered in this program:

1. Oxidation resistance tests - in order to insure oxidizing conditions during testing, a laboratory furnace has been revised to accommodate a closed 4" x 4" "D"-type alumina muffle tube. The muffle tube is constructed so that air, or an oxygen-nitrogen mixture of known composition, may be allowed to flow over the specimen at a controlled flow rate.

All coated specimens were weighed before and after each exposure. In order to determine the time the specimens could withstand the temperature exposure each specimen was removed, cooled to RT, weighed and examined after every hour.

2. Room and elevated temperature tensile strength-room temperature and elevated temperature tensile tests were conducted on coated and uncoated specimens in accordance with ASTM specification E-8-57T. Specimens were heated in air to the desired temperature by quartz lamp radiant heaters.

3. Load cycle test - this test was designed to determine the effect of static loads on coated specimens which are alternately heated and cooled.

4. Transition temperature bend test - it was desirable to determine the effect of the coating and coating process on the ductility of thin sheet. A bend test appeared to be the best method for determining this characteristic since it would provide data on the effects of tension and compression. In addition it provides an indication of the influence of the coating on the base metal ductile-brittle transition temperature.

During the Phase II effort, the following variables are being investigated:

1. Coating deposition temperature.

2. Coating deposition time.

3. Retort seal permeability.

4. Pack density.

5. Pack mix particle size.

6. Pack composition.

Conclusions

Results of tests conducted to date indicate that:

1. Oxidation resistance tests indicate that a Si first coat followed by either a B-Cr coating or a Cr-Al coat offers the best promise for an oxidation resistant coating at 2600°F.

2. Bend tests indicate that sufficient ductility is available to allow for the flexing operations required in handling and fabricating assemblies of the coated sheet materials.

3. Load cycle tests indicate that the coatings have enough ductility at elevated temperatures to afford protection to columbium specimens stressed to just below the yield strength of the metal.

4. The permeability of the retort seal has a profound effect on the oxidation resistance of specimens coated with the Si-Cr-Al and Si-Cr-B systems. This effect must be viewed separately for the two cycles involved in the coating process.

5. The most resistant coatings for 2600°F were produced by depositing the silicide first coat at 2100°F and the Cr-Al or Cr-B second coats at 2200°F.

6. Particle size variations of alumina in the pack showed that a 325 mesh size produced the more oxidation resistant coatings.

MECHANICAL PROPERTIES OF AZ91C-T6 MAGNESIUM CASTINGS

Object

The object of this program was to extend present design allowables for this material into the range between one inch and two inch as cast thickness.

Test Specimens

Approximately 90 specimens one to two inches thick were removed from production castings for this evaluation. The specimens were removed from areas having as cast thicknesses from one to two inches.

General

The test program was designed to show the variation in ultimate strength, yield strength and elongation with changes in the as cast thickness. The investigation was conducted for castings poured under normal casting control conditions, and also for those poured under superior casting control conditions.

Conclusions

The test results indicated that there was a degradation in mechanical properties as the section thickness increased. This was true for both the normal castings and those produced under superior control conditions although the latter had significantly higher base properties.

MATERIALS EVALUATION FOR MODULAR HYDRULICS SYSTEM
BuWeps Contract 59-6019C

Introduction

An integral part of a program designed to develop modular hydraulic components and concepts under the above contract was the evaluation of materials suitable for use under the proposed environmental conditions. The basic requirements for this concept were (1) a capability of operating in the 450°F temperature regime and (2) system operating pressure to be 4000 psi.

Object

To conduct material evaluations for the purpose of determining suitable materials for use in the fabrication of metallic seals, packages and components to be used in a 450°F, 4000 psi integrated hydraulic system.

Conclusions

During the course of this evaluation program materials were screened for potential usefulness in systems of this type. In view of the large range of "end items" envisioned as a result of a program of this type, a group of satisfactory materials was selected rather than just one or two. Various items investigated were machining, heat treating, brazing, plating, welding and bonding. Numerous tests were conducted to establish braze and heat treat cycles which would be useful in joining different materials and to select optimum wear resistant material combinations. Information was obtained on the behavior of MLO-8200 fluid in contact with various alloys, their wear properties and physical properties. The need for fluid compatible lubricants for threads and parts with moving metal to metal surfaces was emphasized.

Since weight was important, and since the systems envisioned were required to operate at temperatures in excess of 400°F, the materials selected were of the stainless steel and heat treatable corrosion resistant alloys. Major materials considered suitable for use were 304 and 321 stainless steels, 17-4PH, AM 350, 416, 440C, 431, A-286 and Inconel X. Also utilized but to a lesser degree were titanium and Vascojet 1000.

DEVELOPMENT OF A NICKEL BASE ALLOY SHEET FOR HIGH TEMPERATURE APPLICATIONS
Contract AF 33(616)-7999

Introduction

The increasing demand for materials to withstand the environmental conditions of future aeronautical and space applications makes it necessary to develop materials having properties in excess of those for commercially available at the present time. Recent material developments for the high temperatures encountered in jet engine turbines have yielded alloys having excellent strength properties in the 1600 to 2000°F temperature range. At present these materials are only available in the form of castings, whereas the normal airframe or space structure is fabricated from sheet alloys.

Object

The object of this program was to develop 0.015 inch thick sheet material having an ultimate strength of 50 ksi at 1900°F and which has adequate oxidation resistance to make it useful.

The most promising alloys for which material was available were (1) INCO 713C, developed by the International Nickel Company and, (2) an experimental alloy developed at the Lewis Research Center in Cleveland, Ohio. Both of these alloys were originally introduced in cast form.

Primarily the program required, (1) the modification of the above alloys by the addition of complex carbides, (2) casting metallurgically sound material in sheet form, (3) the development of heat treatment schedules, and (4) establishment of rolling procedures to produce their nickel alloy sheet with the desired properties.

Because of the high rolling temperature and associated material hardness at these temperatures, a Vought developed rolling mill which eliminates the "spring-back" of conventional rolling mills was utilized.

Results

To date, sound sheet castings, as large as 8" x 16" and 0.10" thick, have been produced with the Lewis Research alloy. The only foreseeable limit at the present time is dictated by the capabilities of the existing equipment at Chance Vought. These castings have been made using the Plasma resistance vacuum furnace developed at Chance Vought. Sheets 0.10 inch thick have also been poured using the INCO 713C alloy and modifications. One of these modifications; named LTV 429, patent applied for; has exhibited strengths in excess of those for either the INCO 713C or the Lewis Research at temperatures of 1900°F and above as well as showing superior oxidation resistance to the Lewis Research alloy. This alloy shows promise as being a base for alloys for use at temperatures in excess of 2100°F since it employs a new stable high temperature strengthening medium.

With respect to rolling mill development a new, rigid, mill has been developed and put into operation (Patent applied for). The results accomplished on this mill to date have proven it superior to conventional mills. Techniques have been developed for rolling sheets of the INCO 713C and Lewis Research alloys down to 0.015" and the LTV 429 to 0.030". In all cases only small, 0.125" deep edge cracks were present and thickness variation has been held to ±0.001".

Tensile tests performed during this investigation show that the cast sheet retains its strength at room temperature and at 1900°F using originally published data as a basis for comparison. Preliminary data indicates that the target strength of 50 ksi at 1900°F for rolled sheet is attainable as soon as optimum heat treatment cycles are established.

VOUGHT EMITTANCE DETERMINATIONS

Introduction

Inconsistencies in certain off-site tests conducted to determine the emittance of zirconia made it necessary to conduct additional tests at this facility for evaluation. To accomplish this work in a short time span necessitated an experimental approach utilizing simple and readily available equipment which would, at the same time, eliminate large and indeterminate sources of error. A thick specimen was used to avoid transmission of radiation from the heat source or incomplete emission. Dual convective heating was selected to allow control of the specimen temperature distribution and prevent contamination. An independent temperature measurement system was incorporated to insure that readings would be unaffected by volume emission or non-grey characteristics.

Procedures

Total emittance was determined by detecting specimen emission and comparing it to black body emittance at the same temperature. The specimen, a disk 1 1/2 inches in diameter and 0.8 inches thick, was tapered to allow secure mounting in machined zirconia bricks. A plasma torch was used to heat the front face, while a propane torch was used to heat the rear face.

The axial temperature distribution was measured by sighting an optical pyrometer into small black body cavities drilled radially into the specimen to its centerline. Surface temperature was specified by a crossplot of temperature vs depth for preliminary data. A heat transfer analysis, using an experimentally determined external temperature profile and independently measured thermal conductivity values will be conducted at several temperature levels to establish the exact shape to be applied to the crossplot for final data.

Total radiation was detected at an angle of about 25° to the specimen normal from a 1/8 inch diameter area in the center of its front face. Spectral radiation from the same specimen area was detected with a Leeds and Northrup optical pyrometer.

A calibration of energy reflected by the specimen from the plasma torch and for direct plasma flame emission was included. This was accomplished by measuring both total and spectral reflected energy as a function of torch distance from the specimen.

Conclusions

It is known that polycrystalline zirconia is translucent at low temperatures in thicknesses of greater than one-tenth inch. An indication of translucency at high temperature was obtained by heating thin disks of zirconia using a plasma torch, and detecting the radiation leaving the hot section at melting. It was found that radiated energy is sensitive to specimen thickness. It is significant to note that the preliminary emittance data run under two sets of subsurface temperature gradients demonstrated a measurably lower value for the case with the coller subsurface.

DEVELOPMENT AND EVALUATION OF A HIGH TEMPERATURE PHOTOELASTIC COATING

Contract No AF 33(616)-7935

Purpose

The purpose of this program was the development and evaluation of a photoelastic coating that could be used for elevated temperature structural testing.

Procedure

The program consisted of the following steps:

1. A number of plastic manufacturers and compounders were asked for information about any of their materials having those properties deemed disirable for a high temperature photoelastic coating.

2. Those materials that showed the most promise were calibrated to determine which one had the best optical properties. The most promising material appeared to be DER 332, catalyzed with Furane 9425.

3. A number of specimens were cast, with various percentages of catalyst and with various post-cure cycles to determine the optimum preparation procedure.

4. The material was tested to determine Youngs modulus vs temperature, thermal coefficient of expansion vs temperature, optical creep properties, and variation in optical sensitivity with time.

5. Testing is now being done with larger specimens to determine the characteristics of the material when applied to full-scale tests.

Conclusions

The coating developed by Chance Vought yields good results up to a temperature of 400°F, and with more refined application techniques, it would probably perform well for very short periods of time in the range of 400°F to 500°F.

EVALUATION OF STRETCHED PLEX 55 FOR AIRPLANE CANOPY APPLICATION

Introduction

Multiaxially stretched Plex 55 is being evaluated at Chance Vought Laboratories to determine its suitability for use in airplane canopies. Static and fatigue tests were performed on elemental specimens of the material and various data comparisons were made.

Since most of the test failures occurred in the plastic through the attachment holes, it is considered that the primary value of the program lies in evaluation of the method of attaching plex 55 to its retaining structure. Further testing to evaluate other aspects of the material is still in progress.

Discussion

The following paragrapns describe the tests which were performed and offer comparisons of the resulting data.

Two different configurations of joints using Plex 55 were compared. One consisted of bolting through the glass with laminated orlon bonded to it; the other employed a bonded butt block. Since the "bolt through" joint proved superior in all respects in the preliminary evaluation, no further work was done on the butt block joint.

Static and fatigue characteristics of the stretched plex were compared with "as cast" material. Stretched plex with four laminates of bonded Orlon edging indicated a static strength improvement of about 8% over "as cast". Fatigue strengths of the two materials were comparable.

Static tests at 170°F revealed a strength reduction of approximately 4% as compared to room temperature tests of the stretched Plex 55.

Attention was given to special methods of preparing the attachment holes in some specimens. Although this procedure did not result in actually increasing overall fatigue life, scatter was greatly reduced by reducing the number of erratic low cycle failures.

Conclusions

In view of the foregoing, stretched Plex 55 would meet the same service requirements as service proven "as cast" acrylic when certain instullation procedures are observed. It is therefore considered structurally acceptable for use as a canopy material.

EVALUATION OF 7075-T73 ALUMINUM ALLOY

Introduction

Service failures have occurred in aluminum hydraulic cylinder barrels which have been attributed to stress-corrosion cracking. Three tentative approaches are available as a means of reducing the incidence of this type failure:

(1) Add material to decrease operating stresses.

(2) Add protective coatings.

(3) Change to a material having more resistance to stress-corrosion.

Approaches (1) and (2) are not considered entirely satisfactory due to either the weight changes involved, or the possibility of coating damage minimizing its protective effects.

Object

The objective of this program is to evaluate the stress-corrosion characteristics of 7075-T73 and 7079-T6 forgings, and to evaluate the effectiveness of several protective coatings in retarding stress-corrosion of 7079-T6 forgings.

Conclusions

Ring type specimens machined from 7075-T73 cylinder barrel die forgings withstood a constant hoop tensile stress of 45 ksi under a 3 1/2% NaCl alternate immersion environment for 12 weeks without failure.

Ring type specimens machined from 7079-T6 cylinder barrel die forgings and subjected to a constant hoop tensile stress of 45 ksi under the same environment failed in an average time of 6 days. When stressed to 30 ksi the average time to failure was 13 days and at 15 ksi failures ranged from 18 days to 12 weeks.

The results of the stress-corrosion tests indicate that the 7075-T73 alloy represents a considerable improvement over the 7079-T6 alloy when stressed in the transverse grain direction as in the parting line area of a forged cylinder barrel.

All of the paint systems used during the program afforded significant protection to the 7079-T6 material. The minimum time for failure was 86 days as opposed to 24 days as the maximum time for failure of unpainted specimens, both stressed to 30 ksi. Special care was taken in handling the painted specimens to insure that the protective coating remained intact since a break in the coating may cause the underlying material to react as a bare specimen.